Sorbents CR-1

Sorbents can be used to pick up spill residuals from tundra and to prevent movement of hydrocarbons into clean areas. Use sorbents if water is not available for flooding or flushing, or if the topography of the site prevents the effective use of booms to contain flooding or flushing water. The choice of which sorbent material to use depends on the substance spilled, season, and availability. The use of sorbents can be labor-intensive compared to other cleanup techniques. Deploying and recovering sorbent material can result in physical damage to tundra; this risk must be carefully weighed against the benefits of removing the residuals. Some examples of sorbent materials include:

- Polypropylene sorbents (pads and boom material) (Figs. 17, 18, and 19)
- Snow (Figs. 20 and 21)
- Granular sorbents (e.g., sawdust or commercially available products)
- Straw
- Pom Poms

Use polypropylene sorbents on crude oil or oil-based substances directly on the tundra surface, or on heavy sheen on standing water in wet or moist tundra or impoundments. A polypropylene sorbent boom can be fixed in position with stakes or fencing to collect floating product in aquatic or wet tundra, or to prevent floating product from moving off site. Sorbent wringers can be used to extend the life of fibrous polypropylene sorbents.

Snow is an effective and readily available sorbent for recovering residues from the tundra surface in winter. Apply snow, recover the snow/residue mixture using hand tools or heavy equipment (Tactic CR-3) and remove for disposal. Other adsorptive materials like granular sorbents or straw may be used if snow is not available.

Figure 17. Sausage booms for containing floating oil

Figure 20. Snow after being used as a sorbent

Figure 18. Sorbent sheets used to recover oil

Figure 21. Using snow as a sorbent

Figure 19. Sorbent used to prevent spread of contaminants

Considerations and Limitations

- Polypropylene sorbents are not effective for non-hydrocarbon spills (e.g. drilling muds or produced water), and are much less effective after surfactants (Tactic CR-8) have been applied.
- Polypropylene sorbents work well on fresh crude, light refined oils, and thick petroleum sheens, but are only partially effective on solidified or weathered oil, highly viscous oil, very thin sheens, or emulsified oil.
- Snow, granular sorbents, and straw are not effective for spill residue floating on water.
- The use of sorbents generates a large amount of waste that requires proper disposal.
- Prolonged use of sorbents on dry tundra may be counterproductive because tundra damage may result.
- This tactic has been adapted from Tactics R-2, R-8 and R-9 in the Alaska Clean Seas Technical Manual (http://www.alaskacleanseas.org/techmanual.htm).

Equipment, Materials, and Personnel

NOTE: Personnel typically work in pairs for sorbent deployment and recovery.

- *Appropriate sorbent material* - to collect spill residue.
- *Stakes or fencing* - to secure sorbent boom to create a sorbent fence.
- *Shovels, rakes, pitchforks* - for application and removal of sorbents.
- *Plastic bags or disposal drums* - for collection of saturated sorbents.
- *Vehicle approved for tundra travel (optional)* - to collect and transport saturated sorbent materials.

Manual Removal

CR-2

Manual removal of spill residue may include collecting spilled substances or contaminated debris with rakes, mops, pitchforks, trowels, shovels (Fig. 22), buckets, portable vacuum systems (Figs. 23 and 24) , and/or sorbent materials (Tactic CR-1). Contaminated material can be placed directly in plastic bags or drums for transfer. If the containers are to be carried to temporary storage areas, their weight should be limited to what one person can safely carry.

Figure 22. Shoveling contaminated gravel

A rubber squeegee (or similar tool) can be used to gently compress and agitate the tundra surface, to squeeze contaminants out of pore spaces of the organic layer. Compression and agitation may be used in conjunction with flooding (Tactic CR-7) or flushing (Tactic CR-8) to enhance recovery of spill residue.

During manual removal activities, avoid damaging plant roots and uncontaminated vegetation. The potential for physical damage to the tundra must be carefully weighed against the benefits of removing additional spill residuals. Workers should be provided with clear guidelines that will allow them to decide when to discontinue manual removal.

Considerations and Limitations

- Take proper precautions to protect tundra from foot and vehicle traffic (Tactic P-4).
- Manual removal is not useful for some non-hydrocarbon spills such as seawater.
- This tactic has been adapted from Tactics R-2 and SH-2 in the *Alaska Clean Seas Technical Manual* (http://www.alaskacleanseas.org/techmanual.htm).

Equipment, Materials, and Personnel

- *Rake* (1 per worker) – recovery.
- *Mop* (1 per worker) – recovery.
- *Squeegee* (1 worker) – agitation.
- *Portable vacuum system* (1 operator) – to recover spilled material.
- *Portable generator* (1 operator) – to power vacuum system.

Figure 23. Vacuuming liquid contaminant

Figure 24. Vacuuming drilling mud

Snow Management CR-3

Moving snow onto or off a site may be useful for a variety of reasons:

- Snow can be used as a sorbent to recover spill residue (Tactic CR-1).
- Snow can be placed on a site to reduce desiccation (i.e., freeze-drying) during winter, prevent early sprouting in spring, and/or provide water to plants during the growing season (Tactic TR-4).
- Snow can be removed from a site so that contaminated vegetation and soil may be scraped (Tactic CR-12).
- Snow can be removed from a site in spring to allow an earlier start to the growing season (Tactic TR-2).

Snow can be handled with heavy equipment or by hand. Snow can be scraped into piles by a dozer (Figs. 25 and 26), and transferred to dump trucks using a front-end loader. A loader with an extension (e.g., push blade in Fig. 27) may be needed to push snow beneath pipes. Manual handling of snow is recommended when working in congested areas, on uneven ground where heavy equipment is likely to scrape high spots, or when there is insufficient snow cover to prevent heavy equipment from damaging the tundra. If the snow is contaminated with spill residue, it must be stored in an approved containment area and proper disposal must be arranged. If the snow is not contaminated, it may be stockpiled nearby or used to build a snow berm to isolate the site during spring snow melt (Tactic CR-3).

Move the snow into piles or windrows using brooms, shovels, or heavy equipment. Transfer the piles to garbage cans, totes, or similar containers. Once a container is full, use a snow machine or Argo to transfer it to a stockpile or a truck on a pad or road (Fig. 28).

Figure 25. Removing snow in spring

Figure 26. Snow removed to excavate contaminated soil

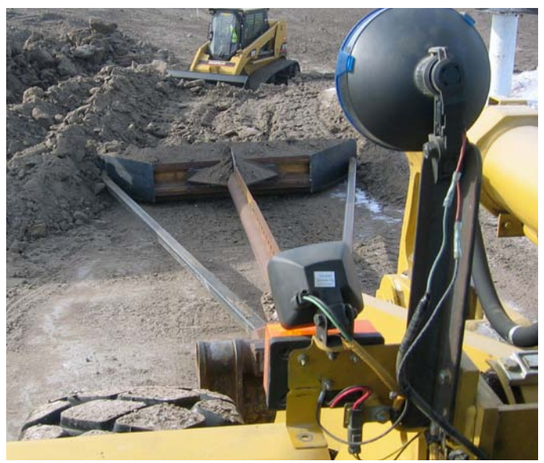

Figure 27. Loader extension pushing material

Figure 28. Removing snow piles

Considerations and Limitations

- Use of vehicles on tundra must comply with applicable tundra travel policies (Tactic P-5).
- Topographic relief (e.g., tussocks, patterned ground) may preclude use of heavy equipment, because high spots are easily scraped.
- Use a spotter for each piece of heavy equipment when working in areas with above-ground pipes or other obstacles.
- Avoid stockpiling clean snow on contaminated areas. Snow piles will persist into the growing season and inhibit vegetation recovery.
- Install a snow fence to prevent snow from accumulating on the site.
- A snow fence can also be used to encourage accumulation of snow on the site.
- Maintain sufficient snow coverage around the site to prevent damage by supporting operations.
- This tactic has been adapted from Tactics R-2 and R-3 in the *Alaska Clean Seas Technical Manual* (http://www.alaskacleanseas.org/techmanual.htm).

Equipment, Materials, and Personnel

- *Snow shovels and brooms* (1 worker per tool) – manual snow removal.
- *Garbage cans or totes* (1 or more workers per container, depending on weight of container) – to carry snow to trailer.
- *Snowmachine or Argo with trailer* (1 operator) – to transport collected snow or containers.
- *Challenger* (1 operator) – to scrape snow into piles for removal.
- *Front-end loader with bucket* (1 operator) – to transfer snow to dump truck.
- *Push blade attachment for loader* (1 operator) – to allow heavy equipment to push snow beneath above-ground pipes.
- *Dump truck* (1 operator) – to transport snow for storage or disposal.

Drainage Protection CR-4

Drainage protection is used to keep contaminants from moving off site. It may be needed during spring breakup and summer when contaminants are mobilized and water is flowing through culverts, or while using treatment tactics such as flooding (Tactic CR-7) or flushing (Tactic CR-8).

A culvert can be blocked using sheet metal, plywood barriers, inflatable culvert plugs, or adjustable weirs (Fig. 29). Plywood or sandbags can also be used as culvert blocks, but require more labor to install. Place blocking materials over the upstream end of the culvert. Plastic sheeting over the outside of the block will decrease the likelihood of water leaking through the block. Block water flow through a culvert only if the impounded water will not threaten the road or raise water levels sufficiently so that additional tundra becomes contaminated.

If blocking a culvert is likely to damage a road or flood uncontaminated areas, a boom may be deployed in a chevron or diversionary configuration, allowing water to flow while deflecting oil from the mouth of the culvert to collection sites along the road (Fig. 30). This technique is especially useful when there is sheet flow of water across the frozen tundra. Boom systems will not provide drainage protection from water-soluble contaminants.

Considerations and Limitations

- Culverts should be unblocked when spill response is complete, to avoid impounding water and possibly washing out the road.
- This tactic has been adapted from Tactics C-2 and C-3 in the *Alaska Clean Seas Technical Manual* (http://www.alaskacleanseas.org/techmanual.htm).

Equipment, Materials, and Personnel

- *Boom* (2 workers) – to deflect floating contaminants from culvert.
- *Anchor system* (2 workers) – to secure boom system.
- *Visqueen* (2 workers) – to prevent seepage through permeable culvert blocks.
- *Inflatable culvert plug* (2 workers) – to block culvert.
- *Air compressor* (1 worker) – to inflate culvert plug.
- *Sheet metal or plywood barriers* (2 workers) – to block culvert.
- *Sandbags* (2 workers) – to block culvert.
- *Flatbed truck* (1 worker) – to transport sandbags.
- *Front-end loader* (1 worker) – to unload sandbags.

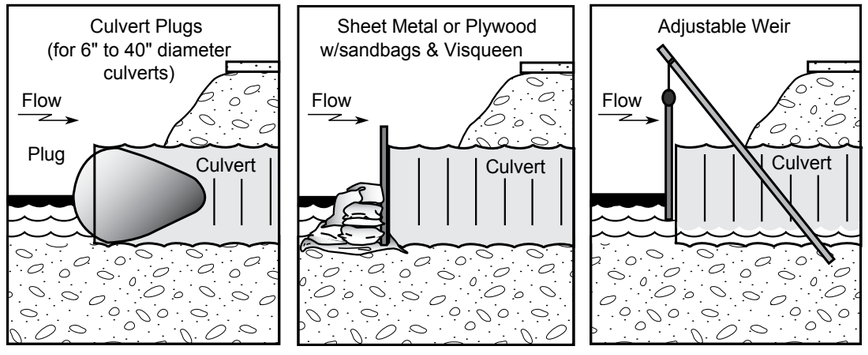

Figure 29. Blocking of culverts

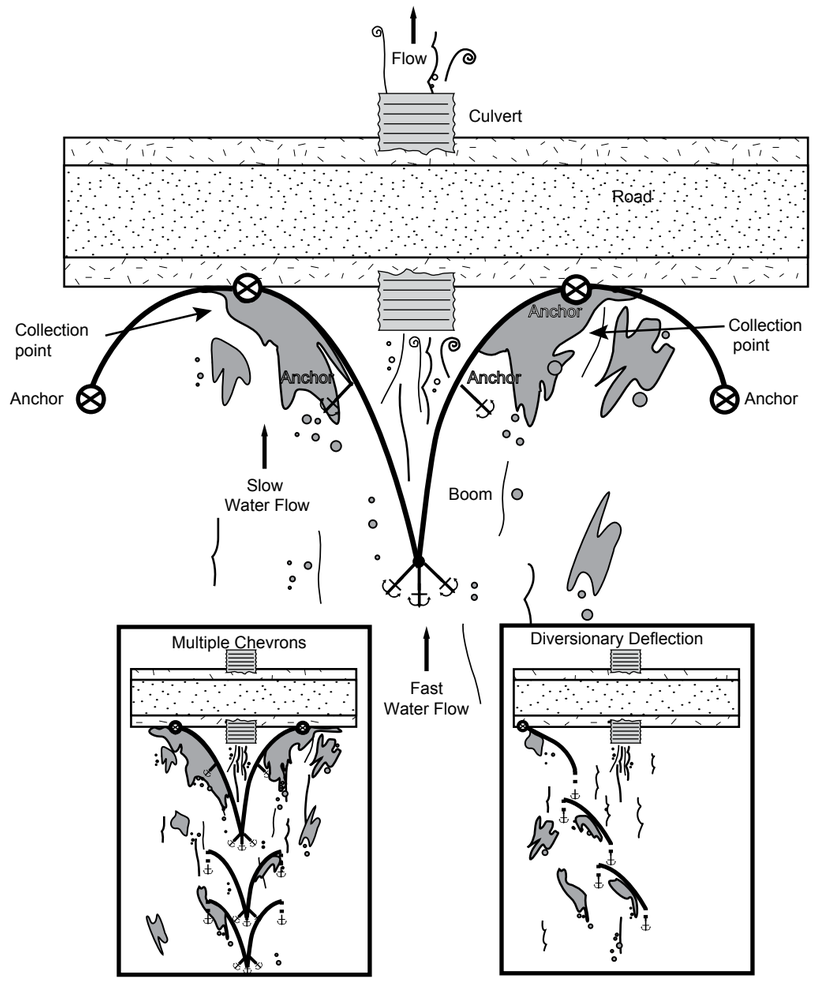

Figure 30. Boom deployed upstream of culvert

Land Barriers CR-5

Land barriers can be used for the following purposes:

- Contain and limit further spreading of contaminants (CR-4).
- Contain water used during flooding (Tactic CR-7) or flushing (CR-8).
- Augment a natural depression or a trench to act as a containment area for recovery (Tactic CR-9).
- Prevent water from flowing onto a site during draining (Tactic TR-1).

Land barriers can be constructed using sand bags (Fig. 31), shore sealing boom (Fig. 32), large diameter hoses filled with water, sheet piling (Fig. 33), and mixtures of snow and ice (Fig. 34). Berms of tundra soil and gravel may also be used, but these are less desirable because they create additional disturbances. The type of barrier chosen depends on the site topography, tundra type, and treatment strategy. When flooding an area, it must be enclosed completely so that the water level can be raised above the ground surface and the floating hydrocarbons recovered. When using a barrier to prevent contaminants from spreading, form the barrier materials into a horseshoe shape to collect contaminants downslope of the flow. To capture flooding or flushing water for recovery, use barriers to augment a natural depression or a trench and to direct water toward the containment area.

Water-soluble substances can infiltrate soil and move horizontally below the surface in all tundra types, thus subsurface barriers (e.g., sheet piling) may be needed to prevent subsurface movement (Fig. 33).

Figure 31. Sand bags

Figure 32. Shore sealing boom

Figure 33. Sheet piling

Considerations and Limitations

- Hydrocarbons will tend to float on wet and moist tundra, but will infiltrate soil in dry tundra.
- Use of vehicles on tundra must comply with applicable tundra travel policies (Tactic P-5).
- Proper disposal of the materials used to construct barriers should be taken into account.
- Shore seal boom is effective if frozen in place, but reinforcement with sandbags or ice berms is needed on both sides where the boom crosses troughs or other low spots.
- Walk on land barriers when possible to avoid damaging tundra.
- All land barrier techniques (except sheet piling) described in this tactic have been adapted from Tactic C-4 in the *Alaska Clean Seas Technical Manual* (http://www.alaskacleanseas.org/techmanual.htm).

Figure 34. Snow and ice berm

Equipment, Materials, and Personnel

- *Appropriate boom material* (2 to 5 workers, depending on site) – to construct land barriers.
- *Backhoe* (1 operator) – to build gravel or tundra berm.
- *Bobcat loader* (1 operator) – to push snow into berm.
- *Water source* (1 operator) – to turn snow berms into ice berms.
- *Front-end loader with bucket* (1 operator) – to move gravel or sand bags.
- *Floating pump and blower* (2 operators) – to fill shore seal boom with air/water.
- *Visqueen or similar heavy plastic sheeting* – to line gravel or tundra berms.
- *Sledge hammer* – to install sheet piling.

Recovery with Skimmers and Pumps

CR-6

Use skimmers (Figs. 35–37) to recover oil floating on the water surface. A variety of skimmers are available that are designed for different situations. The choice of skimmer to use is dependent on factors such as the thickness of the floating oil layer, the depth of water, the degree of weathering of the oil, and whether the oil has been treated with surfactant. Skimmers are most effective when the floating oil is concentrated in a thick layer. Position the skimmer in the area of heaviest concentration of spill residue. A skimmer requires a power pack; a pump with suction and discharge hoses and fittings; and a storage container for recovered product.

At a spill site adjacent to a road or pad, a vacuum truck can be used to drain an area (Tactic TR-1) or to recover pooled spills (Figs. 38—39), flood water (Tactic CR-7) or flush water (Tactic CR-8) from natural depressions, land barrier containment (Tactic CR-5), or trenches (Tactic CR-9). The effective range of a vacuum truck is approximately 200 feet when removing viscous liquids such as crude oil, and 400 feet when removing diesel or water. A Super Sucker can be used for direct suction to remove liquids combined with solids (e.g., gravel) that vacuum trucks cannot handle (Fig. 40).

Submersible pumps or trash pumps can be used to pump areas that are not accessible by vacuum truck or Super Sucker. Submerge the pump or intake hose in the deepest area of an impoundment. Make sure the pump intake or hose end is fitted with a screen to prevent vegetation from clogging the intake hose.

Figure 36. Manta ray skimmer

Figure 38. Vacuum hose recovering oil from low spot

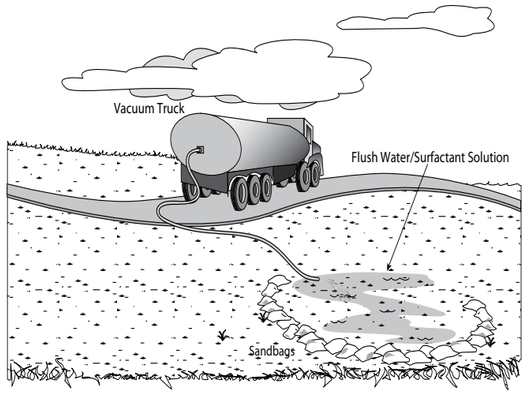

Figure 39. Vacuum truck

Figure 35. Skimming floating oil with slurper skimmer

Figure 37. Rope mop in wet sedge tundra

Figure 40. Super sucker

Considerations and Limitations

- Identify the disposal method or facility to be used and estimate the volume of liquid requiring disposal before skimming or pumping fluids from a spill site.
- Identify the flash points of fluids being recovered.
- Consider ambient temperature when selecting length and diameter of hoses.
- This tactic has been adapted from Tactics R-6 and R-8 in the *Alaska Clean Seas Technical Manual* (http://www.alaskacleanseas.org/techmanual.htm).

Equipment, Materials, and Personnel

- *Any shallow draft skimmer* (e.g., rope mop or Manta ray) (usually 2 operators to deploy and maintain) - to remove floating product.
- *Manta ray skimmer* (1 or 2 operators to deploy and maintain) - to remove floating product.
- *Power pack* - to provide a power source for skimmer.
- *Pumps and hose* (2 operators to deploy and maintain) - to suction product from site.
- *Tank or tanker truck* (1 operator).

Flooding

CR-7

The use of flooding with clean water depends on the nature of the spilled substance:

- ***Crude Oil and Diesel***: Flooding raises or maintains the water level on the tundra surface, reducing the contact of oil with vegetation and making the use of skimmers (Tactic CR-6) or sorbents (Tactic CR-1) more effective (Fig. 41). In dry tundra, flooding also fills pore spaces in the root mat or soil with water, reducing the amount of oil that can infiltrate. Repeated flooding, followed by removal of the floating oil, can greatly increase recovery of hydrocarbons.
- ***Water-Soluble Substances (salts, methanol, glycol)***: Flooding reduces toxicity by diluting the contaminants. The diluted contaminants can then be recovered by pumping (Tactic CR-6). Flooding and pumping can be repeated as needed.

Flooding and flushing (Tactic CR-8) are similar approaches. The potential for erosion is the primary factor to assess when choosing which of these two tactics to use. Use flooding when the potential for erosion is moderate or higher, and use flushing when the potential for erosion is low.

Most sites should be divided into several cells that are small enough to manage efficiently (Fig. 42). Water pressure and flow rate should be kept low to minimize erosion; using a Manta Ray skimmer in reverse to diffuse the input of water works well (Fig. 43). Move the input hose periodically to prevent erosion. Water may be pumped from a nearby tundra pond or creek, or transported to the site using trucks with clean tanks. Do not use seawater or produced water to flood tundra vegetation. Land barriers (Tactic CR-5) are needed to contain water on site (Fig. 44), especially during snowmelt (Fig. 45). In summer, flood with cold or warm water. Hotter water will be needed during winter to allow recovery before the water freezes.

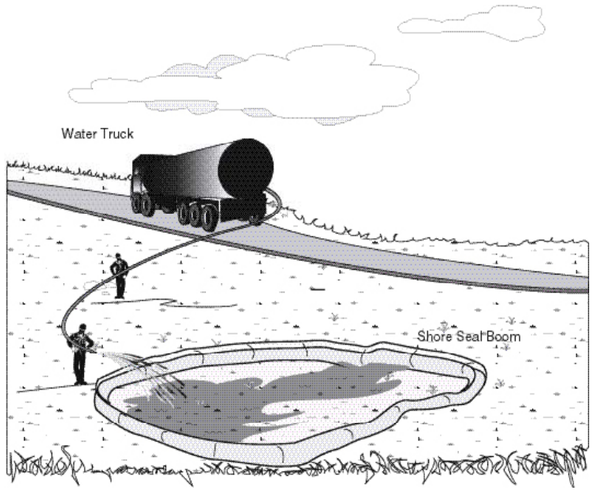

Figure 41. Typical site layout

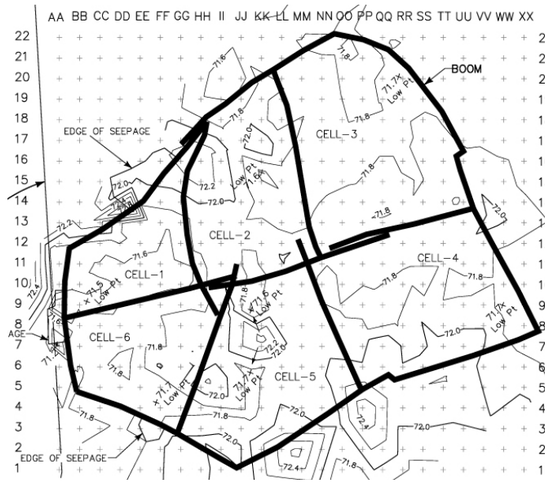

Figure 42. Treatment cells, grid layout, topography

Figure 43. Manta ray skimmer used as inlet hose to prevent erosion

Snow melters can generate very hot water (up to 180°F), and may be the best choice during winter at remote sites with no road access, if the volume of water produced is sufficient. In winter, water can be hauled to the site in heated or insulated tanks.

Surfactants reduce adhesion of crude oil and fuels to vegetation by increasing the ability of water to mix with hydrocarbons. Flooding with surfactants is appropriate for final cleanup of hydrocarbon spills after most of the spilled product has been removed (Fig. 44). Surfactants

Figure 44. Flooding tundra in winter

—*Continued*

Figure 45. Land barriers to contain snow melt within cells

can be mixed with water in tanks, or added to the stream of water flowing out of the input hoses. Dawn™ detergent is the recommended surfactant because it is not toxic to soil microbes at concentrations used during flushing (Jorgenson and Cater 1992a); it is commonly used for cleaning oiled wildlife because of its effectiveness and low toxicity (Hemenway 1990); and it is readily available. Apply Dawn™ at a 0.1% (by volume) concentration. Surfactants also decrease the ability of sorbent pads, booms, and skimmers to recover hydrocarbons, and should only be used after these methods are no longer needed.

Avoid thawing of frozen soil to the extent possible, to minimize infiltration of contaminants into the rooting zone, and exposure of dormant vegetation to freeze-thaw cycles.

Considerations and Limitations

- Maintaining a constant water level is important to prevent exposure of previously unaffected vegetation on higher areas (e.g., polygon rims) to floating or dissolved contaminants, as well as preventing repeated contact of oil with vegetation within the flooded area.
- Create a current in flood water or set-up petroleum collection downwind to remove floating hydrocarbons immediately.
- Surfactants decrease the ability of sorbent pads, booms, and skimmers to recover hydrocarbons, and are generally used during the final flooding, after most of the spilled product has been recovered.
- Surfactants can create enough suds to make operations difficult; add soap carefully.
- Surfactants are not effective for removing substances that mix with water (e.g., salts, glycol).
- Insulated water tanks lose heat at the rate of approximately 10°F every 12 hours.
- Ensure that land barriers (Tactic CR-5) are strong enough to contain water in the flooded area, and that the seal with the tundra surface will not leak.
- If ice berms are used as the land barrier, hot water may cause the berm to fail.
- Ensure water is free of hydrocarbons and salts before using it to flood tundra.
- Assess concentrations of contaminants in floodwater periodically using field screening techniques.
- Flood as few times as possible, to minimize physical damage to vegetation.
- Flooding is feasible during winter, but precautions for worker safety are necessary. Flooding may not be practical at extremely cold temperatures.
- Protect tundra being flooded by walking on plywood boardwalks, sandbags, rig mats, etc.
- Flooding may also be used to irrigate (Tactic TR-4) a site during the growing season.
- This tactic has been adapted from Tactic R-4 in the *Alaska Clean Seas Technical Manual* (http://www.alaskacleanseas.org/techmanual.htm).

Equipment, Materials, and Personnel

- *Water truck or upright tank* (1 operator) - to provide water source.
- *Pumps and suction and discharge hose* (1 to 2 operators each) – to pump water to and from site.
- *Land barriers* (Tactic CR-5) (number of people needed is site-dependent) – to contain water on site and to provide collection point.
- *Clean water* (not seawater or produced water).
- *Plywood, sandbags or rig mats* – to prevent trampling.

Flushing

CR-8

Flushing with clean water is used to mobilize oil from ice (Fig. 46), vegetation, and the tundra surface. If necessary, gently agitate and compress the tundra surface with a rubber squeegee (Tactic CR-2) while directing water flow with the discharge hose. Agitation is most useful in wet tundra where the organic mat is relatively thick and resistant to erosion.

Flushing typically adds and removes water continuously. Keep water pressure and flow rate low enough to minimize erosion. Flush toward a collection area, such as a natural depression or a trench (Tactic CR-9) lined with plastic sheeting, where the oil can be recovered with direct suction (Tactic CR-6) or sorbents (CR-1). A land barrier (Tactic CR-5) is typically needed to contain fluids.

Flushing and flooding (Tactic CR-7) are similar approaches. The potential for erosion is the primary factor to assess when choosing which of these two tactics to use. Use flushing when the potential for erosion is low; use flooding when the potential for erosion is moderate or higher.

Figure 46. Flushing ice to mobilize oil

Figure 47. Flushing tundra with surfactants

Water may be obtained from a nearby tundra pond or creek, or transported to the site in trucks with cleaned tanks. Do not use seawater or produced water to flush tundra vegetation. Flushing water must be contained using land barriers (Tactic CR-5). In summer, flush with cold or warm water. Hotter water will be needed during winter to allow recovery before the water freezes. In winter, water can be hauled to the site in heated or insulated tanks. Snow melters can generate very hot water (up to 180°F), and may be the best choice during winter at remote sites with no road access, if the volume of water produced is sufficient.

Surfactants reduce adhesion of crude oil and fuels to vegetation by increasing the ability of water to mix with hydrocarbons. Flushing with surfactants is appropriate for final cleanup of hydrocarbon spills after most of the spilled product has been removed (Fig. 47). Dawn™ detergent is the recommended surfactant because it is not toxic to soil microbes at concentrations used during flushing (Jorgenson and Cater 1992a); it is commonly used for cleaning oiled wildlife because of its effectiveness and low toxicity (Hemenway 1990); and it is readily available. Apply Dawn™ at a 0.1% (by volume) concentration. Surfactants also decrease the ability of sorbent pads, booms, and skimmers to recover hydrocarbons, and should only be used after these methods are no longer needed.

Surfactants can be mixed with water in tanks, or added to the stream of water flowing out of the input hoses. Most sites should be divided into several cells that are small enough to manage efficiently (Fig. 48).

Avoid thawing of frozen soil to the extent possible, to minimize infiltration of contaminants into the rooting zone, and exposure of dormant vegetation to freeze-thaw cycles.

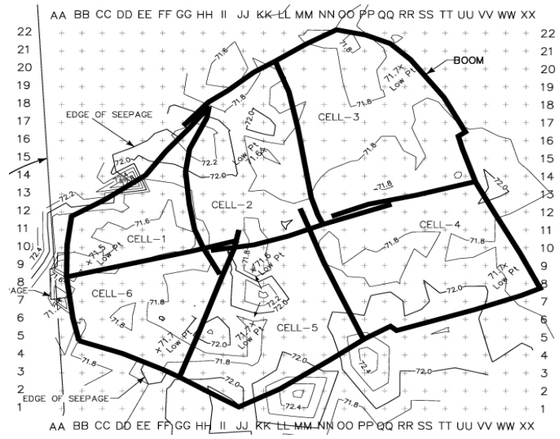

Figure 48. Site divided into 6 cells for treatment

Considerations and Limitations

- Flush as few times as possible, to minimize physical damage to vegetation.
- Move the input hose periodically to minimize erosion.
- Surfactants are not effective for removing substances that mix with water (e.g., salts, glycol).
- Insulated water tanks lose heat at the rate of approximately 10°F every 12 hours.
- Ensure that land barriers (Tactic CR-5) are strong enough to contain water in the area being flushed, and that the seal with the tundra surface will not leak.
- If ice berms are used as the land barrier, hot water may cause the berm to fail.
- Skimmers and sorbents will not be effective after surfactants have been applied to the site.
- Protect tundra being flushed by walking on plywood boardwalks, sandbags, rig mats, etc.
- Ensure water is free of hydrocarbons and salts before using it to flush tundra.
- Flushing is feasible during winter, but precautions for worker safety are necessary. Flushing may not be practical at extremely cold temperatures.
- This tactic has been adapted from Tactic R-4 in the *Alaska Clean Seas Technical Manual* (http://www.alaskacleanseas.org/techmanual.htm).

Equipment, Materials, and Personnel

- *Water truck* (1 operator), tank, tundra pond or stream – to provide water source.
- *Clean water* (not seawater or produced water)
- *Surfactant* (Dawn™ detergent) – to enhance recovery of spill residue.
- *Trash pump* (1 to 2 operators each) – to pump water to and from site.
- *Suction hose* (1 operator) – to take up water from water source.
- *Discharge hose* (3- to 6-inch) with adjustable valve (1 operator) – to discharge water on site.
- *Mop, squeegee* (1 operator) – to agitate and gently compress tundra mat to release spill residue.
- *Land barriers* (Tactic CR-3) (number of people needed is site-dependent) – to contain water on site and to provide collection point.
- *Plywood, sandbags or rig mats* – to prevent trampling.

Trenching CR-9

Trenching is used to intercept the flow of a spilled substance, to divert a spilled substance around a sensitive area, or to capture and recover water used during flooding and flushing (Figs. 49 and 50). Examining the sidewall of a trench can help determine if spilled substances are moving below the ground surface (Fig. 51). Dig trenches by hand or using a trencher attached to a skid loader, tractor, or other type of heavy equipment.

Dig a trench or series of trenches at right angles to the flow, angled slightly downhill to avoid excessive pooling. Place the excavated material on the downhill side of the trenches. Line the sides and bottoms of trenches with plastic sheeting. A trench can be flooded with water to inhibit contaminant penetration and to promote flow toward a recovery device.

Digging trenches in tundra should be considered a last resort, if no other tactic is available to divert or capture water or contaminants. Do not excavate trenches in an area where the excavation will cause more damage than benefit. Excavating trenches in permafrost terrain will disrupt the thermal regime and cause thermal erosion (thermokarst). It may be necessary to backfill trenches (Tactic TR-12) to reestablish a stable thermal regime, and revegetation may be needed to meet rehabilitation goals for the site.

Figure 49. Excavating trench in ice

Figure 50. Excavated trench

Figure 51. Oil exposed in sidewall of trench

Considerations and Limitations

- Vehicle use on tundra must comply with applicable tundra travel policies (Tactic P-5).
- The Bobcat trimmer should be used for trenching only if no other options exist. It can cut a maximum depth of about 4 inches per cut; a trench deeper than 8 inches will be as wide as the Bobcat.
- It may be necessary to survey spot elevations before trenching, to ensure that fluids flow into the trenches.
- A permit may be needed from the landowner before trenching.
- Trenching in tundra should be considered a last resort. Trenching may lead to further disturbance if a natural stream, river, or swale intercepts the path of the trench.
- This tactic has been adapted from Tactics R-7 and C-12 in the *Alaska Clean Seas Technical Manual* (http://www.alaskacleanseas.org/techmanual.htm).

Equipment, Materials, and Personnel

- *Shovels* (1 worker per tool) – to hand dig trench.
- *Skid loader, or tractor with trenching attachment* (1 operator) – to dig trench.
- *Visqueen or similar heavy plastic sheeting* – to line trench.

Burning Contaminated Vegetation

CR-10

Burning is used primarily to volatilize and oxidize residual contaminants from vegetation after other tactics have been used to recover most of the spilled substance. This tactic is especially useful for light coatings on leaves of sedges and grasses that are elevated above the tundra surface (Figs. 52–53). Burning was first tested on the North Slope in the late 1970's (Fig. 54). This tactic is not appropriate for removing pooled product from the ground surface. The relatively large amount of heat required to burn pooled product could 1) cause vertical migration of the substance into the rooting zone and 2) induce thermokarst in the underlying tundra soil.

Typically, one worker uses a metal rake to orient oiled leaves and stems more or less vertically. A second worker uses a weed burner, which consists of a flame nozzle, hosing, and a propane tank. The flame nozzle is held just above the contaminated vegetation until the vegetation is burned down to stubble. Burn residue can be recovered with hand tools, but the benefit of recovery should be carefully weighed against the potential for causing additional physical damage to the tundra.

The risk of damage from burning is relatively modest in moist and wet tundra dominated by sedges. Much of the biomass of these plants, including the buds from which new leaves sprout, is deep enough to be protected from the heat of the fire. Use additional caution in drier tundra where shrubs, mosses and lichens are abundant, as these growth forms have little or no ability to sprout from belowground parts.

Figure 52. Propane torch burning contaminted vegetation

Considerations and Limitations

- Burning vegetation contaminated with weathered oil or fuel may produce a residue that is difficult to clean up.
- Burning as soon as possible after a spill will increase the likelihood of complete combustion because fewer of the volatile components (e.g., benzene) in the spilled substance will have evaporated.
- Follow proper safety procedures and use personal protective equipment, as required.
- Burning should be considered only when there is minimal risk that the fire will spread to unaffected areas. This consideration is especially important when dry sedge and grass leaves (i.e., dead plant litter) are present.
- Permission must be obtained from the Alaska Department of Environmental Conservation and potentially from the U.S. Environmental Protection Agency before burning tundra vegetation.
- This tactic has been adapted from Tactics B-2 and SH-10 in the *Alaska Clean Seas Technical Manual* (http://www.alaskacleanseas.org/techmanual.htm).

Figure 53. Burning a thin layer of surface contamination

Equipment, Materials, and Personnel

- *Metal rake* (1 worker) – to orient oily vegetation.
- *Weed burner with propane tank* (1 operator) – to ignite spilled residue and vegetation.
- *Fire extinguisher* (1 operator) – to suppress unwanted fire.
- *Fans* (1 operator) – to increase burning efficiency (optional, if conditions are appropriate).

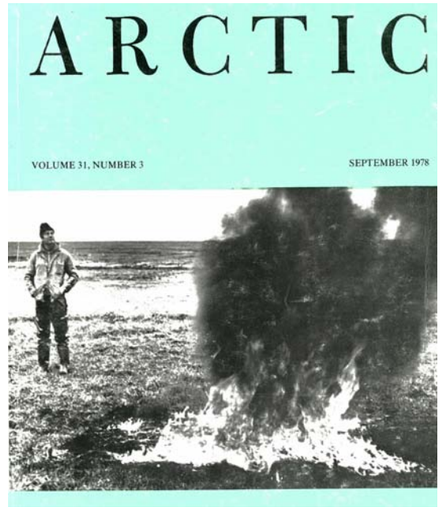

Figure 54. 1979 edition of *Arctic*

Removing Contaminated Vegetation

CR-11

Remove contaminated vegetation to prevent remobilization of spill residuals, and to promote recovery of the remaining live plant tissues. Only remove above ground vegetation that is dying or dead (Fig. 55). Avoid damaging plant roots to maximize sprouting of new shoots and leaves. Collect the trimmed material into bags by hand, raking, or shoveling, and remove from the site for proper disposal. Minimize contact between contaminated and uncontaminated vegetation.

General Considerations and Limitations

- Place plywood on the ground to minimize trampling and shearing of roots.
- This tactic is less likely to cause physical damage when the ground is frozen and vegetation is dormant.
- This tactic is labor-intensive and may not be suitable for large sites where site access would cause physical damage to areas unaffected by the spill.

Equipment, Materials, and Personnel

Note: Personnel typically work in pairs when cutting and trimming vegetation.

- *String or line trimmer* (1 operator) – to cut grasses and sedges (non-woody vegetation) on larger sites.
- *Scissors or knives* (1 worker) – to cut vegetation on smaller sites.
- *Hand clippers, pruners, or brush cutter* (1 worker) – to cut woody plant stems.
- *Rakes* (1 worker) – to collect clipped and cut plant materials.
- *Bags for collecting cut leaves*.
- *Cans for collecting woody plants*.

Figure 55. Trimming vegetation

Mechanical Removal: Scraping, Trimming, and Brushing

CR-12

Use scraping, trimming, and brushing to recover contaminants on the tundra surface while leaving as much soil as possible, to preserve live buds, roots, and rhizomes (Figs. 56—60). Mechanical removal can be used while the ground is frozen or partially thawed. Trimmers are especially effective for breaking up contaminated ice and packed snow. Mechanical removal can also be effective in spring when air temperatures are still well below freezing, but solar heating is sufficient to thaw the surface soil after snow has been removed. Contaminants can be easier to see when soil is partially thawed (Figs. 61 and 62), and a spotter can direct the operator, but the depth of removal must be controlled carefully to minimize tundra damage. This tactic works best for viscous substances, such as crude oil, which tend to remain on the tundra surface rather than penetrating into the soil.

Figure 56. Scraping soil saturated with oil

Figure 57. Seventy-two-inch trimmer

Figure 58. Forty-two-inch trimmer

Figure 59. Twenty-four-inch trimmer

Figure 60. Rotating brush

Figure 61. Oily spots in scraped tundra

Figure 62. Oily spots in trimmed tundra

Damage from scraping and trimming can be severe in moist and dry tundra, because the plants' rooting systems are often within 1 inch of the tundra surface. In contrast, much of the rooting systems of plants in wet tundra are deeper than 1 inch below the tundra surface, and are more likely to be left in place after mechanical removal.

Use a mechanical brush to clear the area of snow (Tactic CR-3) and expose the tundra surface (Fig. 63). Trimmed ice and snow can be removed with a Super Sucker vacuum truck or by methods described in the snow removal tactic (Tactic CR-3). Adjust the blade or trimmer to remove a thin layer of soil. Transfer contaminated material to dump trucks and transport to appropriate waste disposal facilities.

Considerations and Limitations

- Identify the disposal method or facility to be used and estimate the volume requiring disposal before mechanical removal begins.
- Most or all lichens and mosses will be removed by scraping and trimming.
- Scraping and trimming may be impractical for areas with small-scale topographical relief (e.g., tussock tundra, patterned ground).
- Avoid stockpiling clean snow on contaminated areas. Snow piles will persist into the growing season and inhibit vegetation recovery.
- Use of vehicles and heavy equipment on tundra must comply with applicable tundra travel policies (Tactic P-5).
- Trimming should be employed as soon as possible following the gross removal of the non-frozen spilled substance, to limit vertical movement of contamination.
- This tactic is not intended to remove pooled product from the ground surface.
- To avoid damage to the root mat, trimming should be limited to the tops of the plant shoots.
- Method of trimming, including equipment, materials and personnel, will be determined by the size and topography of the site.

Equipment, Materials, and Personnel

- *Trimmer* (one operator) – to trim the spill-affected surface ice (size of trimmer will be dependent on size of spill and topography).
- *Grader/dozer/Bobcat* (1 operator) – to scrape snow and contaminated surface vegetation.
- *Spotter* - to visually identify boundaries where scraping or trimming is needed.
- *Front-end loader and/or Super Sucker* (one to two operators) – to pick up trimmed or scraped ice and snow.
- *Brooms, rakes, and shovels* (one worker per tool) – to sweep up loose ice and snow not picked up by previous methods.
- *Front-end loader* (1 operator) – to transfer scraped or trimmed material into end dumps.
- *Dump truck* (1 operator) – to transfer scraped or trimmed material to disposal site.

Figure 63. Mechanical brush for clearing snow

Excavation for Offsite Disposal

CR-13

Excavation of tundra soil may be necessary when treatment goals include the rapid and complete removal of spill residuals. Excavation should be considered if contaminant levels are high enough to be toxic to plants, if the entire organic mat is saturated with contaminants, or when other treatment options have been deemed inadequate for achieving the treatment goals.

Dozers, backhoes (Fig. 64), trimmers (Figs. 65–66), and jackhammers (Fig. 67) can be used to excavate the organic mat and underlying mineral soils. Contaminated soil is typically removed from the site for treatment or disposal.

The depth of infiltration by contaminants determines the depth of soil that should be removed. It may be feasible to remove only the organic mat, before the spilled material infiltrates down to mineral soil. Minimize the volume of soil excavated by using a spotter to direct the operator to contaminated areas. For example, at many sites, contaminants tend to flow into a network of polygon troughs, leaving higher areas relatively unaffected. However, soil testing (Tactic AM-4) is often needed to identify areas to excavate, because even highly visible substances (e.g., crude oil) are difficult to see under certain conditions, especially during winter with artificial lighting. Consider removing only "hot spots" and leaving as much tundra as possible intact to prevent excessive damage to the tundra (see Tactic AM-3).

In most cases the excavated area must be backfilled (Tactic TR-12) to minimize the risk of thermokarst (Fig. 68). Therefore, a source of approved replacement material must be identified before excavation begins. Excavation may create a tundra environment suitable for some plants but not others. Backfilling may not be necessary if creation of aquatic habitat is an acceptable rehabilitation option.

Figure 65. Trimmer excavating contaminated soil


Figure 66. Site after excavation with trimmer


Figure 64. Backhoe excavating contaminated soil


Figure 67. Excavating frozen soil with jackhammer


Figure 68. Edge of backfilled area after excavation

Considerations and Limitations

- Remove soil only to the depth to which contaminants have infiltrated.
- Identify a source of approved fill material before beginning excavation.
- Ensure backfill has suitable properties (e.g., particle size, relative amounts of gravel, sand, and silt).
- Allow for settling after backfilling in order to maintain proper surface grade relative to the surrounding tundra.
- Monitoring surface elevation over time may be necessary to document site stability.
- Consider disposal options and required approvals before using this tactic.
- On-site sampling of contaminated soil can expedite the excavation process.

Equipment, Materials, and Personnel

- *Backhoe or trimmer* (1 operator) – to excavate contaminated soil or ice.
- *Front-end loader* (1 operator per loader) – to transport excavated material.
- *Dump truck* (1 operator) – to transport contaminated material to disposal site.
- *Polyethylene sheeting* – lining for stockpiles.
- *Spotter* – to guide excavation of visibly contaminated soil.